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EFFECTS OF URBAN RUNOFF AND WASTE-WATER EFFLUENT ON WILSONS CREEK AND JAMES RIVER NEAR SPRINGFIELD, MISSOURI

U. S. GEOLOGICAL SURVEY

Water-Resources Investigations 80-27

Prepared in cooperation with
City of Springfield, Missouri
Sanitary Services

U. S. DEPARTMENT OF THE INTERIOR
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UNITED STATES DEPARTMENT OF THE INTERIOR

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CONVERSION FACTORS

For use of those readers who may prefer to use the International System of Units (SI) rather than inch-pound units, the conversion factors for the terms used in this report are listed below.

Multiply inch-pound units	By	To obtain SI units
acre	0.4047	hectare (ha)
feet (ft)	0.3048	meter (m)
cubic feet per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
inch (in.)	25.40	millimeter (mm)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)

To convert temperature in °C (degrees Celsius) to °F (degrees Fahrenheit), multiply by 1.8 and add 32.

Effects of urban runoff and wastewater effluent on Wilsons Creek and James River near Springfield, Missouri

By Wayne R. Berkas

ABSTRACT

Data from a network of stations on Wilsons Creek and James River were used to document the hydrologic conditions prior to upgrading the Southwest Wastewater Plant near Springfield, Missouri. Statistical T tests on the means of water-quality parameters from James River upstream and downstream from the confluence of Wilsons Creek shows that there is a significant difference for all parameters except temperature and dissolved silica at the 0.05 probability level. Regression analysis shows coefficient of determinations (R^2) greater than 0.64 for discharge with dissolved sodium, dissolved chloride, and dissolved potassium, and for specific conductance with dissolved sodium, dissolved chloride, and dissolved sulfate at the station downstream from Wilsons Creek. This is due to the consistent quality of the effluent from the Southwest Wastewater Plant on Wilsons Creek. Water-quality monitor stations upstream and downstream from the wastewater plant indicate that the effluent from the plant has a degrading effect on dissolved oxygen in Wilsons Creek and James River. Also, the monitors indicate that rainfall washes poor-quality water into Wilsons Creek from the urbanized Springfield area. Overall, the runoff has the effect of diluting the effluent from the wastewater plant. Flood-frequency estimates were made, although it was not possible to fully account for urban effects because of scant data.

INTRODUCTION

A major problem in the Springfield area, Mo., was the degradation of water quality in Wilsons Creek and James River by effluent from the Southwest Wastewater Plant and storm runoff. Some summer storms, combined with the wastewater plant's effluent discharge, resulted in the total depletion of dissolved oxygen in Wilsons Creek and extremely low levels in the James River downstream and Wilsons Creek (Emmett and others, 1978). Also, odorous and unsightly conditions were caused by the sewage effluent in Wilsons Creek, which created an aesthetic problem for the Wilsons Creek National Battlefield. In 1969 the Federal Water Pollution Control Administration (now known as the U.S. Environmental Protection Agency) recommended that a tertiary system be added to the Southwest Wastewater Plant.

In September 1970, a 10-acre sewage lagoon was added, then abandoned in October 1977 when the tertiary system became active.

Purpose and Scope

For several years water-quality and streamflow data have been collected by the U.S. Geological Survey in cooperation with the city of Springfield, Mo. The city requested a statistical analysis of the water-quality data before completion of the tertiary system, and that the streamflow and water quality monitoring data be interpreted during this period. Flood-magnitude and frequency data were also requested for the Wilsons Creek area. Those results, as reported herein, may serve as a base from which future changes in water quality in Wilsons Creek and James River can be determined.

Description of Area Studied

Wilsons Creek, in Greene and Christian Counties of southwestern Missouri, has a drainage area of approximately 84 mi^2. The upper one-third of the basin is within the city limits of Springfield, which had a population of 120,000 in 1970. After passing the Southwest Wastewater Plant at about midlength, Wilsons Creek flows through Wilsons Creek National Battlefield and into the James River.

Wilsons Creek basin lies on the Springfield Plateau, which is underlain by rocks of Mississippian age. The terrain is gently rolling in the divide area with moderate relief near the rivers. Sinkholes are common throughout the basin, and the elevation ranges from 1,350 feet at the divide to 1,100 feet at the James River. The vegetation on the ridges is predominantly agricultural with the valleys being forested. A more in-depth discussion of the area is presented by Emmett and others (1978).

Previous Investigations

Since 1954, reports have documented fish kills and odor problems in Wilsons Creek that have resulted from urban runoff, industrial waste, and wastewater effluent. This report will not provide a synopsis of each of these previous reports because a summary of each is presented in a 1969 report by the Federal Water Pollution Control Administration.

The Federal Water Pollution Control Administration's report was the result of a study to determine what steps could be taken to alleviate the fish kills and odor problems. This study showed that the initial runoff during a storm event in Wilsons Creek basin was of very poor quality, but was followed shortly by much better quality water. This initial poor-quality water resulted from rain washing inorganic chemicals, nutrients, and oxygen consuming meterial from the urbanized areas into Wilsons Creek. The report recommended that a holding reservoir be built on Wilsons Creek upstream from the Southwest Wastewater Plant to hold the initial poor-quality water until it could be diluted to an acceptable quality. At the present (1979) the holding reservoir has not been completed.

The Federal Water Pollution Control Administration also reported that the Southwest Wastewater Plant contributed to fish kills and odor problems. The quality of the sewage effluent caused a sludge pile and anaerobic conditions to occur in Wilsons Creek where the effluent was discharged. This and the high ammonia concentrations in the effluent caused odor problems in Wilsons Creek. When high-flow conditions occurred, some of the sludge pile was transported downstream and caused the oxygen to become depleted, killing the fish. It was recommended that a tertiary polishing lagoon be added to the Southwest Wastewater Plant to remove excess biodegradable material and nitrogen. This was accomplished in September 1970 with the completion of a 10-acre lagoon. The lagoon was abandoned in October 1977, after the plant was expanded and began providing tertiary treatment of the wastewater.

DATA-COLLECTION SITES AND METHODS

Six data-collection stations have been established in the Wilsons Creek basin (fig. 1). Water-quality samples were collected periodically from James River upstream and downstream from Wilsons Creek (sites 5 and 6) beginning August 1964, with monthly sampling beginning August 1967. Water samples at these two stations were analyzed for physical characteristics, common inorganic consituents, major nutrients, and bacteria. These data are published annually by the U.S. Geological Survey (1964-78).

Water-quality monitor stations are located on Wilsons Creek above and below the Southwest Wastewater Plant (sites 3 and 4) and on James River below Wilsons Creek (site 6). Since October 1972, river stage, water temperature, specific conductance, dissolved oxygen, and pH were measured continuously. These data are published annually by the U.S. Geological Survey (1972-78).

Two rainfall-runoff gages are located within the Springfield city limits. One is located on North Fork Wilsons Creek (site 1) and has a drainage area of 5.3 mi^2. The orifice for the stage recorder is 6 inches above the bottom of the concrete culvert, so with unobstructed flow conditions discharges less than 5.8 ft^3/s will not be recorded. The other rainfall-runoff gage is located on Wilsons Creek (site 2) with the orifice of the stage recorder in the creek, attached to a bridge pier. The drainage area of this station is 17.8 mi^2. Data collection for both stations began in 1973. Data are available upon request from the U.S. Geological Survey, Rolla, Mo.

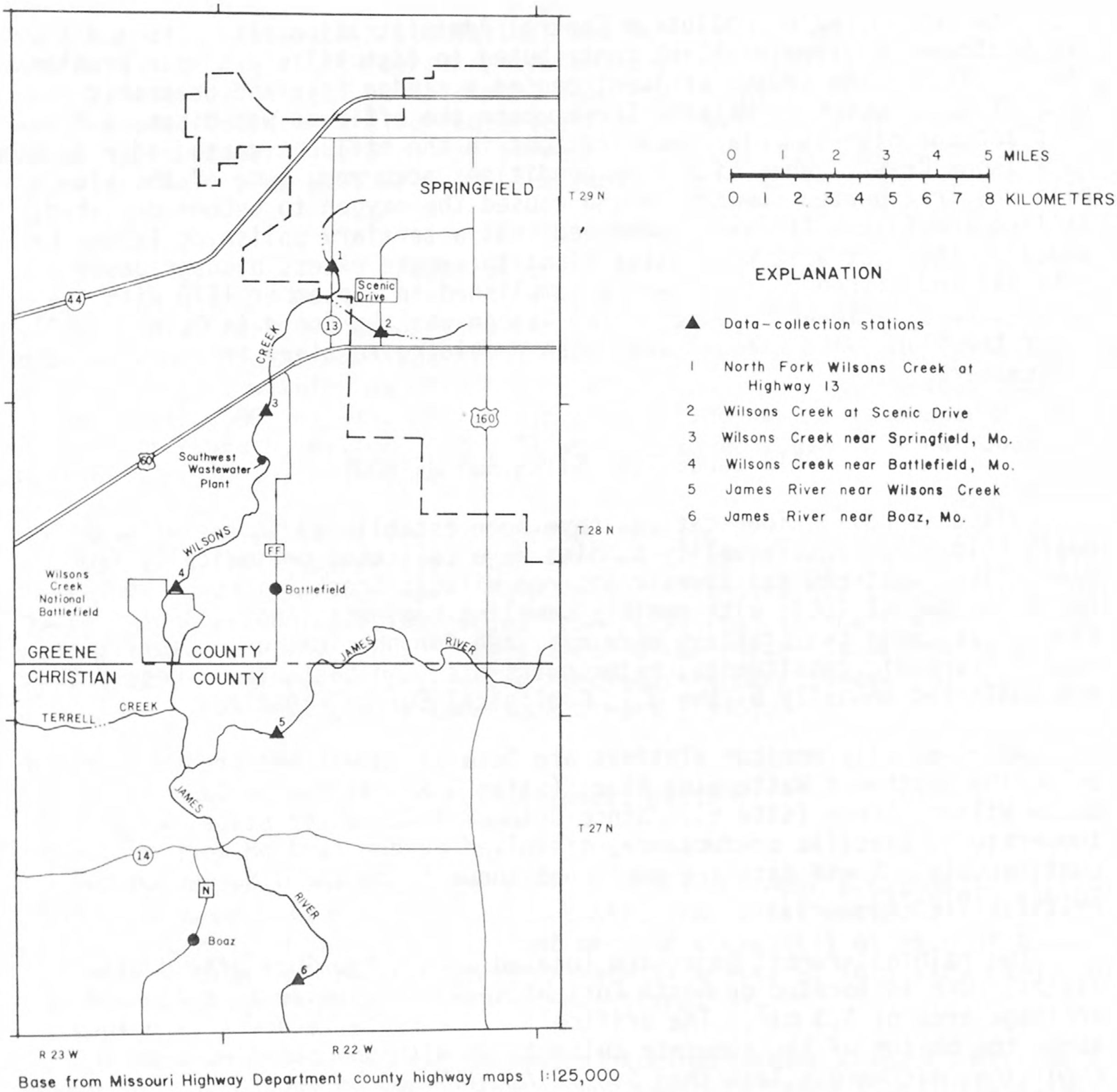

Figure 1. Location of data-collection stations on Wilsons Creek and James River.

STATISTICAL ANALYSIS

Water samples analyzed for physical characteristics, common inorganic constituents, major nutrients, and bacteria were collected at the stations James River near Wilsons Creek (site 5), and James River near Boaz (site 6). Statistical analysis is used at these two stations to determine if the effluent from the Southwest Wastewater Plant changed the quality of the water in James River. The Statistical Analysis System (SAS) programs called TTEST (computes T statistics) MEANS (simple univariate descriptive statistics), FREQ (frequency table), and GLM (least-square regression) were used (Barr and others, 1976).

Water-quality data collected from these two sites are divided into two time periods according to treatment changes at the Southwest Wastewater Plant. The first period began in August 1964 and ended September 1970 when a sewage lagoon was added to the treatment facilities. The second period began September 1970 and ended October 1977 when the lagoon was abandoned and replaced by the new tertiary system.

T-tests

The time periods before and after the completion of the sewage lagoon at each station were tested using the TTEST procedures in SAS for equal and unequal variances. The T test is a statistical procedure used to determine if a sample distribution mean is equal to another sample distribution mean. If the mean and variances are equal, then the two sample distributions are considered equal or the same. SAS's TTEST procedure tests for equal variances and means assuming either equal or unequal variances. The appropriate T-statistic of the means was used depending whether TTEST showed equal or unequal variances. All constituents tested showed no significant differences between the means at the 0.05 probability level, except for fecal streptococci and fecal coliform at James River near Boaz (site 6). The statistics show that the means of fecal streptococci and fecal coliform were less after the initiation of the sewage lagoon. Because no significant difference was found for the other constituents, the data were not divided into time periods for future statistical testing.

Means, standard deviations, medians, and ranges were computed on 20 parameters at both stations (sites 5 and 6) to help characterize the water quality in James River upstream and downstream from Wilsons Creek and are presented in table 1. These parameters are:

Specific conductance	Alkalinity as $CaCO_3$
Dissolved sulfate (SO_4)	Bicarbonate (HCO_3)
Dissolved chloride (Cl)	Dissolved solids (residue at 180°C)

Dissolved manganese (Mn)	Chemical oxygen demand (COD)
Dissolved silica (SiO_2)	Dissolved oxygen (DO)
Dissolved sodium (Na)	Dissolved potassium (K)
Dissolved iron (Fe)	Total phosphorus (P)
Dissolved magnesium (Mg)	Total nitrate (N)
Dissolved calcium (Ca)	Temperature (°C)
Hardness as $CaCO_3$	pH

Regression Analysis

Regression analysis is the process of fitting a model to a random independent variable and a random dependent variable. Independent variables are variables that can be set to a desired value or easily observed. With a model, a dependent variable value can be estimated from a known independent variable value. The coefficient of determination (R^2) obtained from the analysis is a measure of the predictive ability of the model. R^2 measures the percentage of total variation about the mean of the dependent variable explained by the regression equation (Draper and Smith, 1966). For example, an R^2 value of 0.80 means that the regression model explains 80 percent of the total variation about the mean.

Regression analysis was performed using the GLM procedure outlined in SAS which uses least-squares regression. Discharge, specific conductance, alkalinity, and temperature are the independent variables with all the other constituents as dependent variables. Those pairs of independent and dependent variables having an R^2 value greater than or equal to 0.64 at any of the two stations are used in this report.

Regression analysis fits a linear relationship to the data. If a curvilinear relationship applies, it must be transformed into a linear relationship in order to use the SAS procedures. Regressions were run for three equations, one linear and two curvilinear. The curvilinear equations $(Y+1)=b(X+1)^m$ and $(Y+1)=bm^X$ were chosen because a log transformation yields a linear model. A value of 1 was added to each value in these equations to eliminate the possibility of taking the log of 0.0. The most significant equation, along with its R^2 value, is presented in table 2.

Table 2 shows that there is low correlation between discharge and any other parameter at the James River near Wilsons Creek station. At James River near Boaz there is high correlation for discharge versus dissolved sodium, dissolved potassium, and dissolved chloride. The correlation at the Boaz station is due to a consistent quality of effluent discharged from

Table 1.--Statistical relationships of water-quality parameters for James River near Wilsons Creek and James River near Boaz for the period August 1964 to September 1977

[Results in milligrams per liter, except as indicated]

Parameter	Mean	Standard deviation	Median	Number of samples	Range
Specific conductance (μmho/cm at 25°C)--	333	39	340	148	164-----507
Dissolved sulfate (SO_4)--------------	11.9	5.2	10.0	126	6.0----39
Dissolved chloride (Cl)---------------	8.2	3.7	7.5	126	2.3----37
Dissolved manganese (Mn) [μg/L]--------	23.8	30.4	10.0	100	0.0---170
Dissolved silica (SiO_2)-------------	7.6	2.0	7.7	100	0.7----11
Dissolved sodium (Na)---------------	4.5	3.0	4.1	100	2.4----32
Dissolved iron (Fe) [μg/L]-------------	24.9	26.5	20.0	70	0.0---130
Dissolved mangesium (Mg)---------------	6.8	1.3	6.8	100	2.4-----9.4
Dissolved calcium (Ca)---------------	53.0	6.6	53.0	100	32------71
Hardness as $CaCO_3$----	160	17.8	160	100	97-----192
Alkalinity as $CaCO_3$--	146	17.3	148	140	72-----176
Bicarbonate (HCO_3)---	178	21.0	180	141	88-----215
Dissolved solids (residue at 180°C)	193	22.9	190	121	109-----241
Chemical oxygen demand (COD)--------------	6.4	7.8	4.0	119	0.0----50
Dissolved oxygen (DO)---------------	8.8	1.8	8.7	148	5.0----13.3
Dissolved potassium (K)----------------	1.8	0.7	1.6	100	0.8-----5.2

Table 1.--Statistical relationships of water-quality parameters for James River near Wilsons Creek and James River near Boaz for the period August 1964 to September 1977--continued

Parameter	Mean	Standard deviation	Median	Number of samples	Range
		James River near Wilsons Creek--continued			
Total phosphorus (P)----------------	0.06	0.07	0.04	98	0.0-----0.5
Total nitrate (N)----	1.3	0.63	7.4	100	0.0-----3.2
Temperature (°C)-----	16.0	6.9	17.0	145	0.5----32
pH (in units)--------	----	----	7.9	148	7.3-----8.3
		James River near Boaz			
Specific conductance (μmho/cm at 25°C)--	438	108	410	146	234-----810
Dissolved sulfate (SO_4)--------------	18.7	12.7	15.0	124	5.0---110
Dissolved chloride (Cl)--------------	24.6	18.5	17.0	124	5.3----87
Dissolved manganese (Mn) [μg/L]--------	65.7	57.5	50.0	98	0.0---300
Dissolved silica (SiO_2)------------	8.0	2.2	8.3	98	1.6----12
Dissolved sodium (Na)--------------	15.6	11.4	12.0	98	3.4----49
Dissolved iron (Fe) [μg/L]--------	35.0	34.0	30.0	70	0.0---200
Dissolved magnesium (Mg)--------------	5.8	1.3	5.7	100	1.3-----9.1
Dissolved calcium (Ca)--------------	59.8	7.1	60	98	29------75
Hardness as $CaCO_3$----	173	20.0	170	98	82-----210
Alkalinity as $CaCO_3$--	163	23.8	162	140	78-----230
Bicarbonate (HCO_3)---	199	29.0	197	140	96-----280
Dissolved solids (residue at 180°C)------------	258	74.4	239	120	141-----648

Table 1.--Statistical relationships of water-quality parameters for James River near Wilsons Creek and James River near Boaz for the period August 1964 to September 1977--continued

Parameter	Mean	Standard deviation	Median	Number of samples	Range
Chemical oxygen demand (COD)--------	12.2	10.4	10.0	119	0.0----64
Dissolved oxygen (DO)----------------	6.9	2.7	7.0	146	1.0----13.3
Dissolved potassium (K)-----------------	3.1	1.7	2.6	98	1.1-----8.4
Total phosphorus (P)--	1.33	1.05	0.92	100	0.15----4.4
Total nitrate (N)-----	2.4	1.24	2.3	98	0.0-----7.7
Temperature (°C)------	15.5	6.9	16.0	142	0.0----29
pH (in units)---------	----	----	7.7	146	7.2-----8.5

Table 2.--Summary of relationships among variables measured and sampled at James River near Wilsons Creek and James River near Boaz

Variables: Independent (X)	Variables: Dependent (Y)	Coeficient of determination (R^2)	Most significant regression equation
James River near Wilsons Creek			
Discharge	Dissolved sodium	0.259	$Y=8.811(X+1)^{-0.104}-1$
Do.	Dissolved potassium	.079	$Y=3.370(X+1)^{-0.44}-1$
Do.	Dissolved chloride	.268	$Y=16.039(X+1)^{-0.127}-1$
Specific conductance	Alkalinity	.744	$Y=0.699(X+1)^{0.920}-1$
Do.	Hardness	.692	$Y=1.212(X+1)^{0.842}-1$
Do.	Dissolved calcium	.736	$Y=0.222(X+1)^{0.947}-1$
Do.	Dissolved sodium	.495	$Y=1.078(1.005)^{X}-1$
Do.	Dissolved chloride	.457	$Y=1.289(1.006^{X}-1$
Do.	Dissolved sulfate	.248	$Y=3.102(1.004)^{X}-1$
Do.	Dissolved solids	.763	$Y=1.067(X+1)^{0.895}-1$
Alkalinity	Hardness	.870	$Y=1.578(X+1)^{0.927}-1$
Do.	Dissolved calcium	.873	$Y=18.65(1.007)^{X}-1$
James River near Boaz			
Discharge	Dissolved sodium	.871	$Y=266.9(X+1)^{-0.536}-1$
Do.	Dissolved potassium	.662	$Y=16.71(X+1)^{-0.263}-1$
Do.	Dissolved chloride	.775	$Y=379.2(X+1)^{-0.537}-1$

Table 2.--Summary of relationships among variables measured and sampled at James River near Wilsons Creek and James River near Boaz--continued

Variables		Coefficient of determination (R^2)	Most significant regression equation
Independent (X)	Dependent (Y)		
	James River near Boaz--continued		
Specific conductance	Alkalinity	0.560	$Y=0.163X+91.17$
Do.	Hardness	.584	$Y=8.611(X+1)^{0.499}-1$
Do.	Dissolved calcium	.546	$Y=3.367(X+1)^{0.480}-1$
Do.	Dissolved sodium	.847	$Y=0.742(1.007)^{X}-1$
Do.	Dissolved chloride	.897	$Y=0.155X-44.28$
Do.	Dissolved sulfate	.661	$Y=4.108(1.003)^{X}-1$
Do.	Dissolved solids	.851	$Y=0.605(X+1)^{0.993}-1$
Alkalinity	Hardness	.853	$Y=2.307(X+1)^{0.851}-1$
Do.	Dissolved calcium	.840	$Y=0.849(X+1)^{0.841}-1$

the Southwest Wastewater Plant. The Boaz station also has high correlation for specific conductance versus dissolved sodium, dissolved chloride, and dissolved sulfate, whereas the Wilsons Creek station does not. This is also due to the influence of a consistent effluent quality from the plant.

Wilsons Creek data show high correlation for specific conductance with alkalinity, hardness, and dissolved solids, and for alkalinity with hardness and dissolved calcium. The Boaz station also shows high correlation for those relations.

INFLUENCE OF STORM RUNOFF ON WATER QUALITY

The purpose of this section is to describe the effect that storm runoff has on the water quality in Wilsons Creek upstream and downstream from the Southwest Wastewater Plant and James River. Five continuous-record stations are used for this purpose (fig 1); the two stations on the uppermost part of Wilsons Creek basin are rainfall and discharge stations. Both basins are urbanized, but the Wilsons Creek station (site 2) is more highly urbanized. At the North Fork Wilsons Creek station (site 1), low-stage levels are not recorded because the station is used only in the study of urban storm runoff. The North Fork Wilsons Creek station has a drainage area of 5.3 mi^2, and the Wilsons Creek station has a drainage area of 17.8 mi^2. The other three stations, located downstream on Wilsons Creek and James River, are water-quality and discharge stations. These stations provide a continuous record of dissolved oxygen, temperature, pH, specific conductance, and discharge. Located on Wilsons Creek upstream and downstream from the Southwest Wastewater Plant (sites 3 and 4) and on James River downstream from Wilsons Creek (site 6), they indicate what effect the effluent from the plant has on Wilsons Creek and James River. The range of water-quality data collected at these stations is presented in table 3.

In the Springfield area, the type of rainfall event depends on the time of the year. During the winter, rainfall occurs as frontal storms of low intensity and long duration. During the summer months, rainfall can occur as convective storms of high intensity and short duration or as frontal storms of high intensity and long duration. One of each type of rainfall event was chosen to show how the water quality in Wilsons Creek is affected by urban runoff. The three rainfall events are a winter frontal event, a series of three summer convective events, and a summer frontal event.

Winter Frontal Event

The winter frontal event occurred on February 12, 1977. According to the National Oceanic and Atmospheric Administration (1977), there was no snow cover reported at the Springfield Weather Service Office on February 9. Althouth the snow cover officially melted on February 9, there probably

Table 3.--Range of data collected at water-quality monitors

Parameter	Maximum	Minimum
Wilsons Creek near Springfield, Mo. October 1972 to September 1977		
Temperature------------	29.0°C	0.0°C
Specific conductance---	1,520 μmho/cm at 25°C	70 μmho/cm at 25°C
Dissolved oxygen-------	19.4 mg/L	0.2 mg/L
pH---------------------	9.1	7.1
Wilsons Creek near Battlefield, Mo. October 1972 to September 1977		
Temperature------------	27.0°C	2.5°C
Specific conductance---	1,430 μmho/cm at 25°C	100 μmho/cm at 25°C
Dissolved oxygen-------	13.5 mg/L	0.0 mg/L
pH---------------------	8.4	6.5
James River near Boaz, Mo. October 1972 to September 1977		
Temperature------------	30.5°C	0.0°C
Specific conductance---	914 μmho/cm at 25°C	109 μmho/cm at 25°C
Dissolved oxygen-------	14.6 mg/L	0.0 mg/L
pH---------------------	8.7	6.9

was still ice and snow on some north-facing slopes and sheltered areas. The low temperature for February 12 was 0.5°C with a high of 10.5°C. Because of the recently melted snow cover, the antecedent-moisture conditions for the storm were wet. The hyetographs (rainfall amount per time), hydrographs, and water-quality monitor records are presented in figures 2-6.

The hydrographs show that North Fork Wilsons Creek contributed very little to the discharge in lower Wilsons Creek. Most of the runoff during this storm event originated in the highly urbanized upstream reach of Wilsons Creek.

The temperature records before the runoff at the Springfield station ranged between 0.0° and 4.0°C, while the temperature before runoff at the Battlefield station ranged between 10.0° and 12.0°C, indicating that the effluent from the wastewater plant has a major effect on the temperature in lower Wilsons Creek during the winter. Statistical analysis of the means (T test) indicates that the effluent does not have a significant effect on the temperature in James River. When the storm runoff occurred, the temperature at the Battlefield station fell to about 6°C. The temperature at Boaz did not change appreciably because its temperature was already about 6°C.

The pH at the Springfield station was higher than at Battlefield and Boaz before the runoff. This difference in pH can be attributed to the effluent from the wastewater plant. The runoff caused the pH at the Springfield station to drop to 8.0 and the pH at the Battlefield station to rise to 8.0. The pH at the Battlefield station dropped after the runoff due to the lower pH of the sewage effluent.

The dissolved-oxygen record shows the sewage effluent lowers the dissolved oxygen at the Battlefield and Boaz stations. The dissolved-oxygen concentration at Boaz is higher than at Battlefield because much of the oxygen demand has been utilized by the time it reaches this station and because of the dilution effect from the James River.

When the storm runoff occurred, the dissolved-oxygen concentration at Springfield and Battlefield dropped rapidly. Rainfall, containing oxygen consuming material, flushed the urbanized area causing the rapid decrease or dissolved oxygen on the leading edge of the runoff. At the Battlefield station, the drop was also due to suspension of sludge caused by increased turbulence of the larger flow. The dissolved-oxygen concentration increased after this initial flush, which has higher dissolved-oxygen concentrations than Wilsons Creek at base flow.

Both Wilsons Creek stations show a peak in specific conductance at the leading edge of runoff followed by a large drop. This peak can be attributed to high concentrations of dissolved constituents in the runoff from the urbanized areas. The large drop is due to dilution by runoff which characteristically has a low specific conductance. Specific conductance at Boaz is less affected by the runoff.

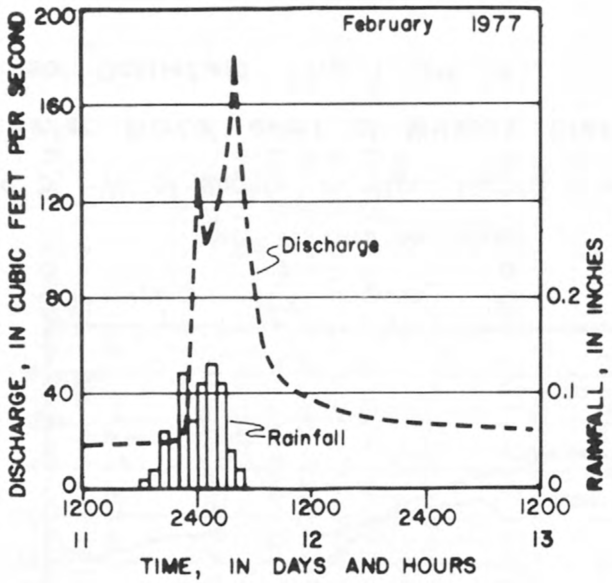

Figure 2. Rainfall and runoff for the winter frontal event for Wilsons Creek at Scenic Drive (fig. 1, sta. 2).

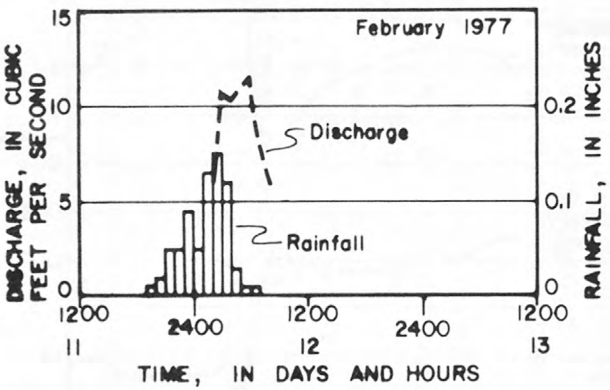

Figure 3. Rainfall and runoff for the winter frontal event for North Fork Wilsons Creek at Highway 13 (fig. 1, sta. 1).

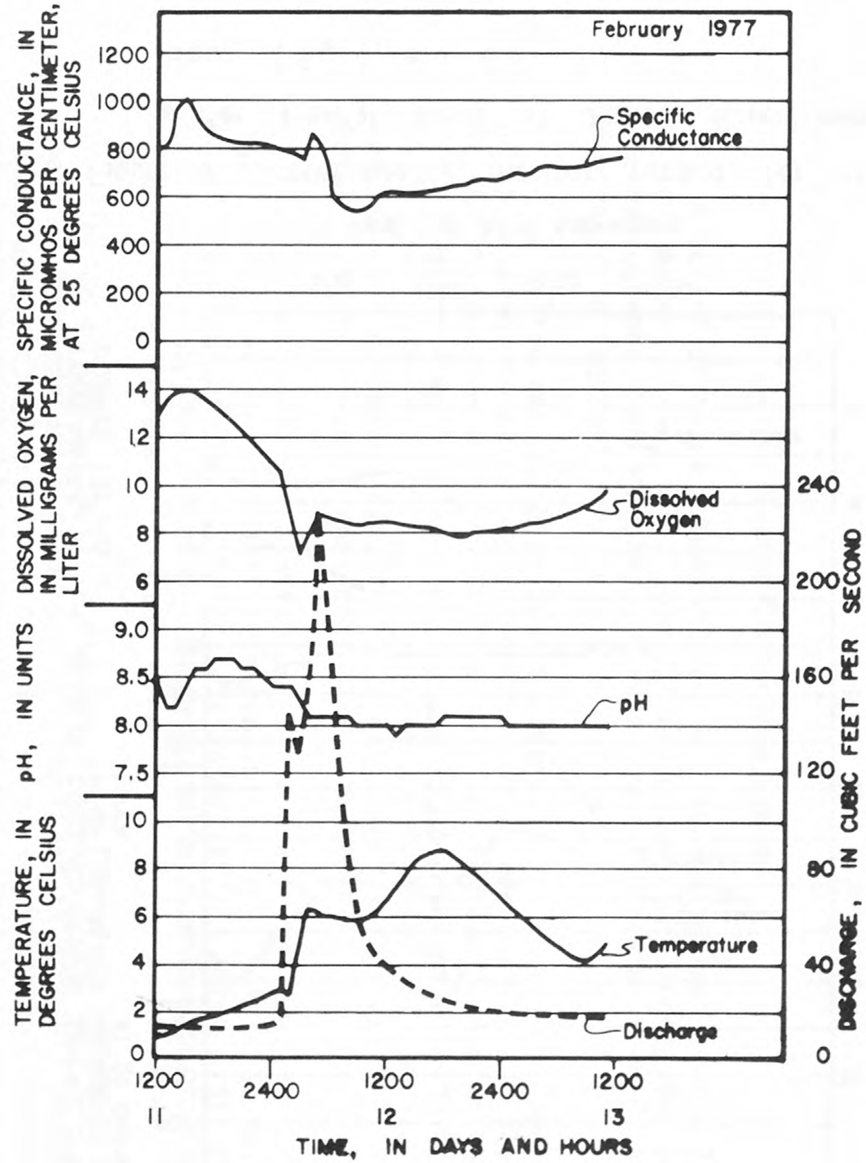

Figure 4. Water-quality monitor record for the winter frontal event at Wilsons Creek near Springfield (fig. 1, sta. 3).

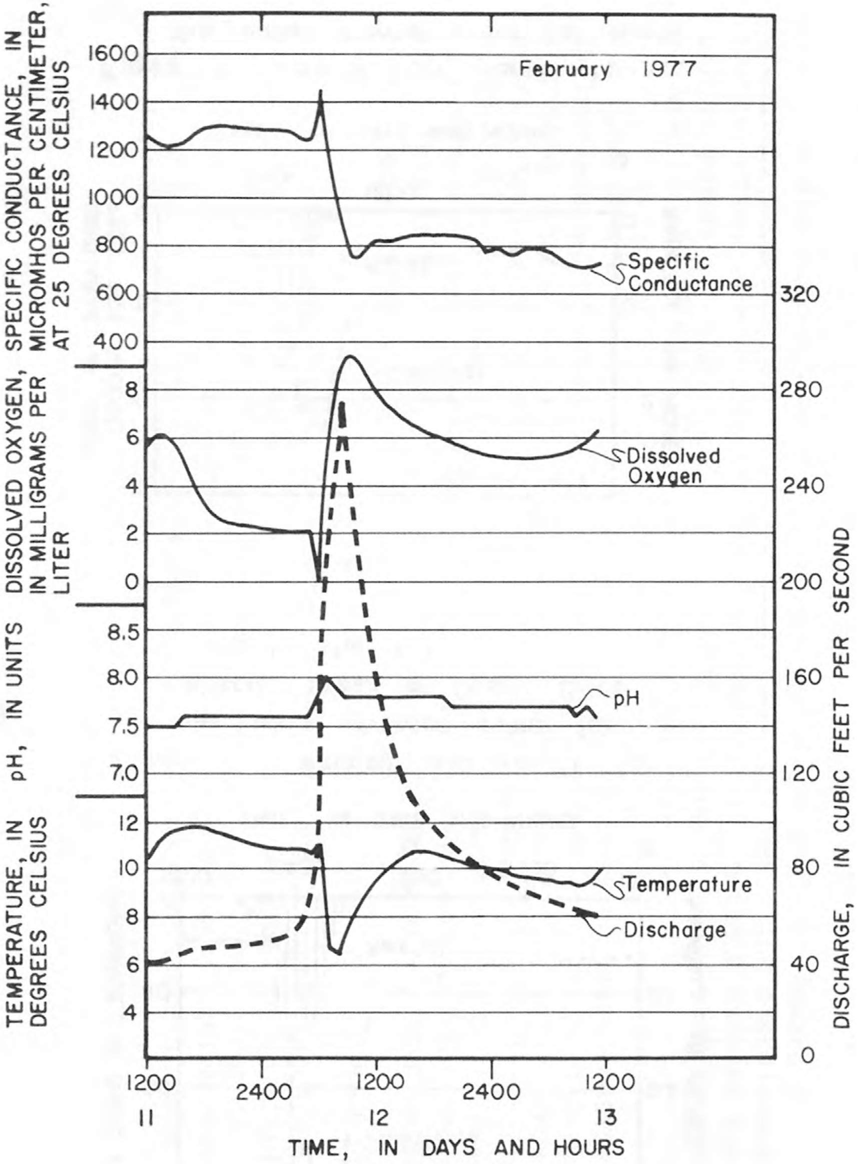

Figure 5. Water-quality monitor record for the winter frontal event at Wilsons Creek near Battlefield (fig. 1, sta. 4).

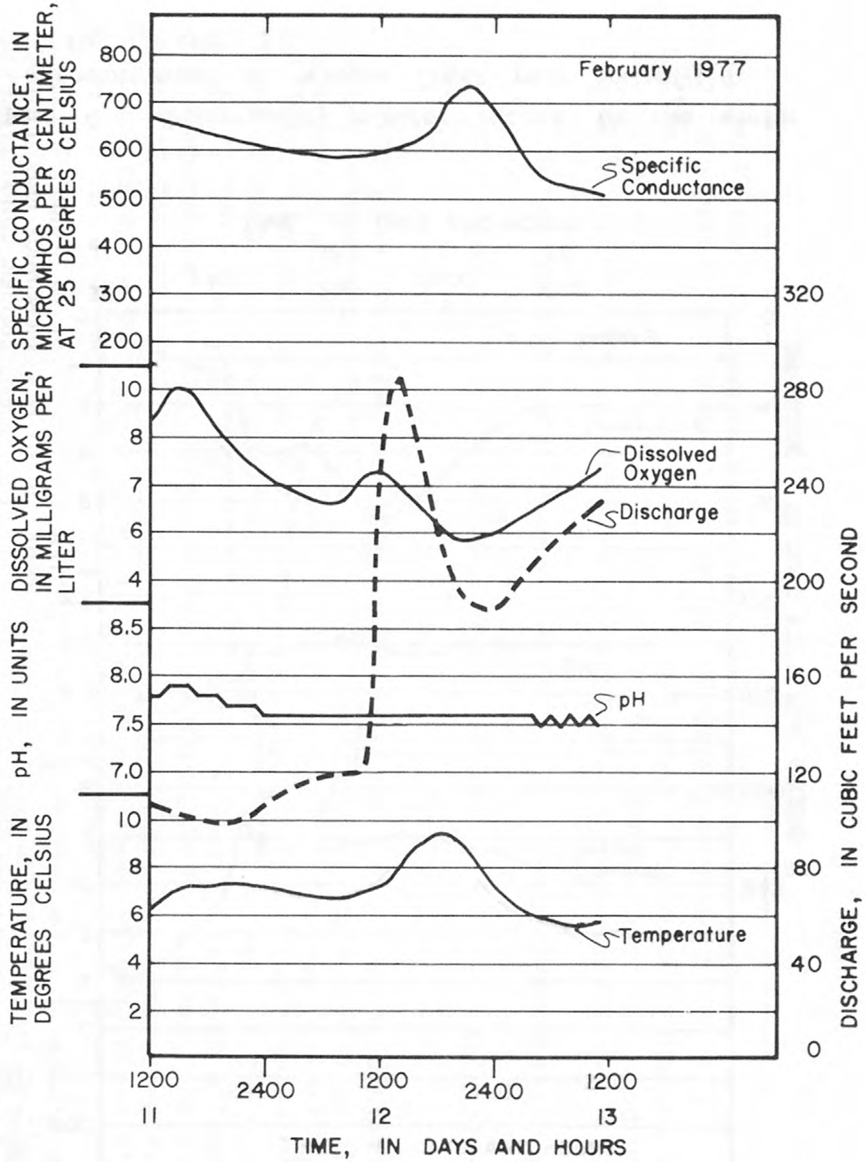

Figure 6. Water-quality monitor record for the winter frontal event at James River near Boaz (fig. 1, sta. 6).

Summer Convective Event

A series of three summer convective storms occurred over a 3-day period, August 11-13, 1977. The antecedent-moisture conditions were dry. The hyetographs, hydrographs, and water-quality monitor records are presented in figures 7-10.

The hyetograph and hydrographs presented for this event are composed of the hyetograph at the North Fork Wilsons Creek station and the hydrograph at the Wilsons Creek station. There was no recordable flow at North Fork Wilsons Creek and the rain gage was not functioning at Wilsons Creek for this event. The hyetograph and hydrographs show that dry antecedent conditions had a major effect on discharge from North Fork Wilsons Creek, because no storm runoff was recorded in the basin.

In summer months precipitation will normally be lower in temperature than surface water, so runoff from precipitation will have a cooling effect on streams. According to temperature record at all three stations, this is exactly what happened. The wastewater-plant effluent seems to have little effect on the temperature in the summer.

The pH at the Springfield station decreases after the first runoff peak and then gradually returns. This decrease is probably caused by the runoff water being of a lower pH. The pH at the other two stations is apparently unaffected by the runoff, but their initial pH was already lower than that of the Springfield station.

A characteristic of pH is shown in the Boaz record. For low flows the pH shows a diurnal fluctuation along with the dissolved oxygen. During respiration or dedomposition in the water, CO_2 is produced which is converted to carbonic acid. The greater the concentration of carbonic acid, the lower the pH becomes. During photosynthesis CO_2 is used, lowering the carbonic-acid concentration, thus raising the pH. So, with changes in CO_2 due to photosynthesis, the pH will rise and fall with dissolved oxygen.

At low flow dissolved-oxygen concentrations at all three stations exhibit diurnal fluctuations. Except during daylight, dissolved oxygen at Battlefield is usually near 0.0 mg/L (milligrams per liter). This is attributed to the effluent from the Southwest Wastewater Plant. It appears from the record at James River that digestion of the effluent was complete by the time it reached the Boaz station for the flow conditions. If a water-quality monitor was located above Wilsons Creek on James River, a comparison of dissolved-oxygen record could be made to see if digestion was actually complete.

When the runoff occurred, the dissolved oxygen at each station changed differently. At Springfield no significant changes occurred. This could have been due to the lack of biodegradable material in the initial flush, or

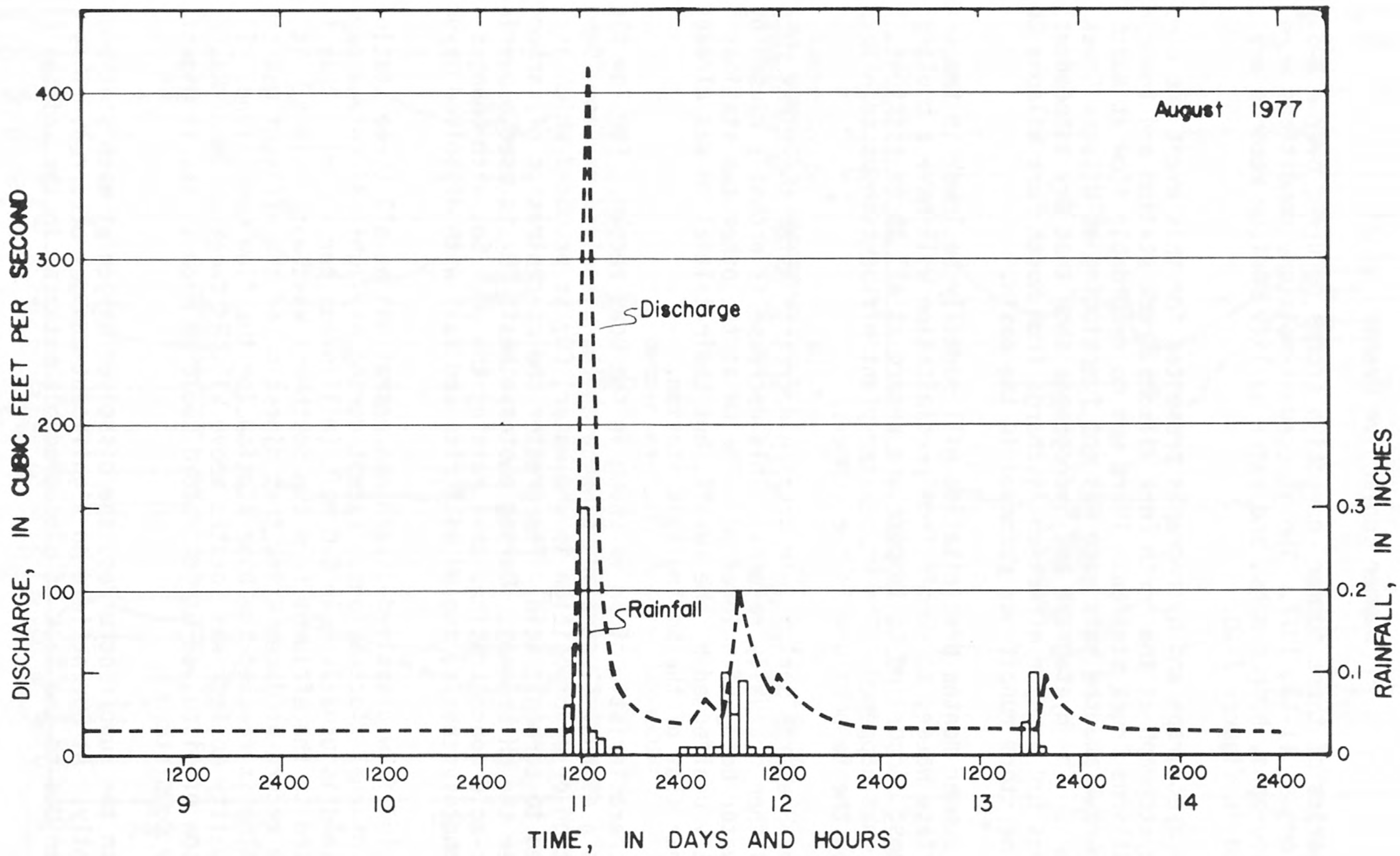

Figure 7. Rainfall for North Fork Wilsons Creek at Highway 13, and runoff for Wilsons Creek at Scenic Drive for the summer convective event (fig. 1, stas. 1 and 2).

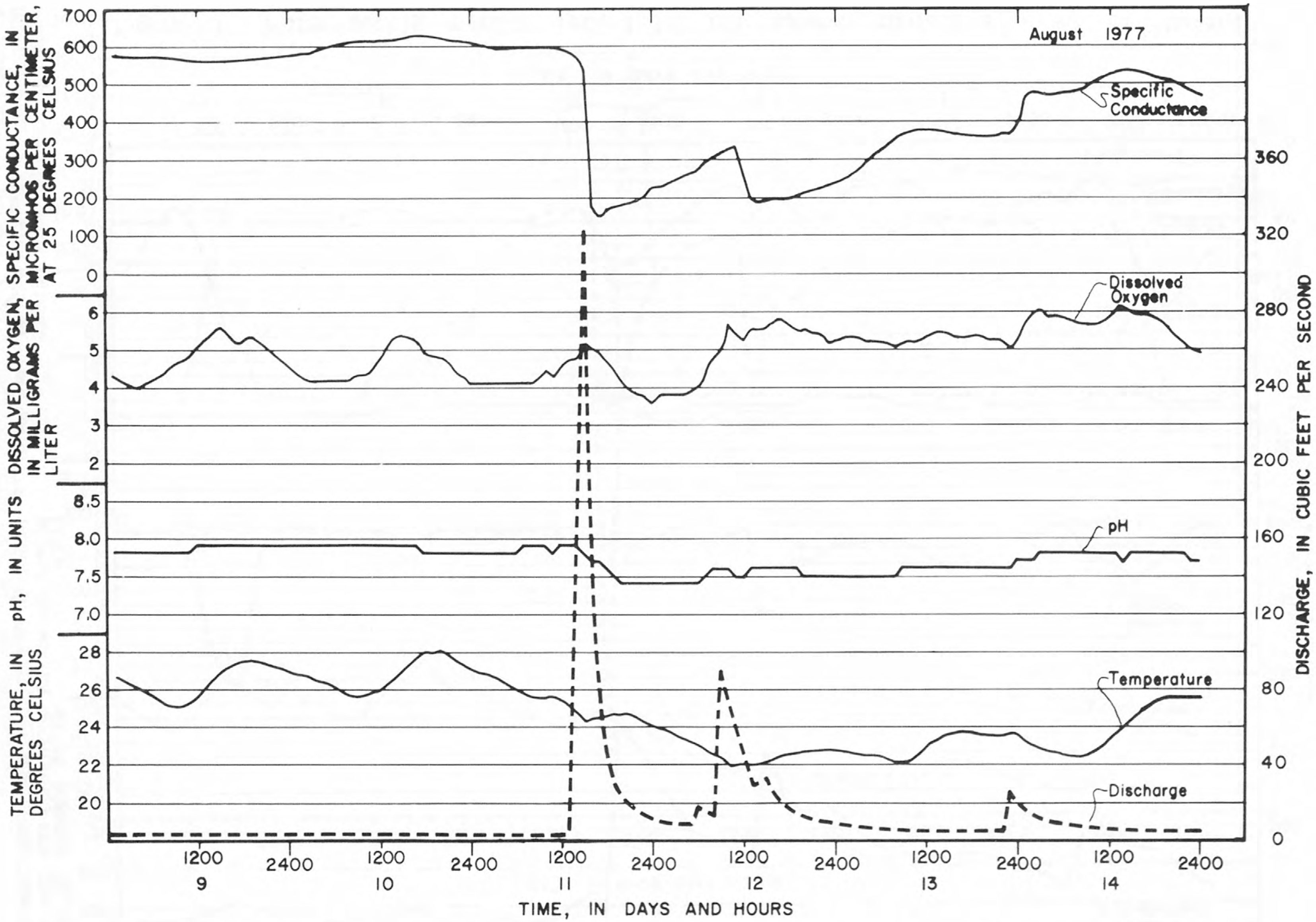

Figure 8. Water-quality monitor record for the summer convective event at Wilsons Creek near Springfield (fig. 1, sta. 3).

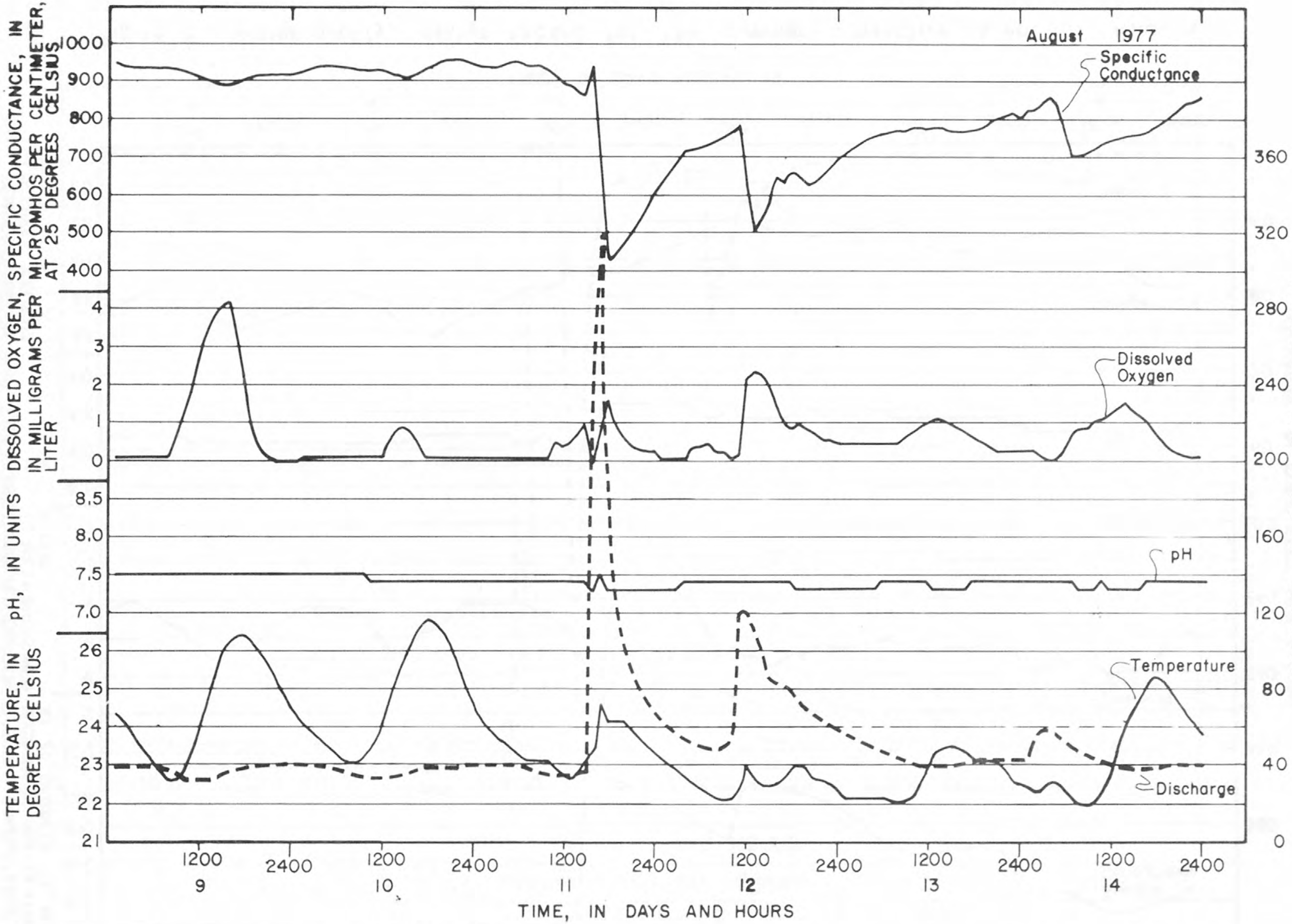

Figure 9. Water-quality monitor record for the summer convective event at Wilsons Creek near Battlefield (fig. 1, sta. 4).

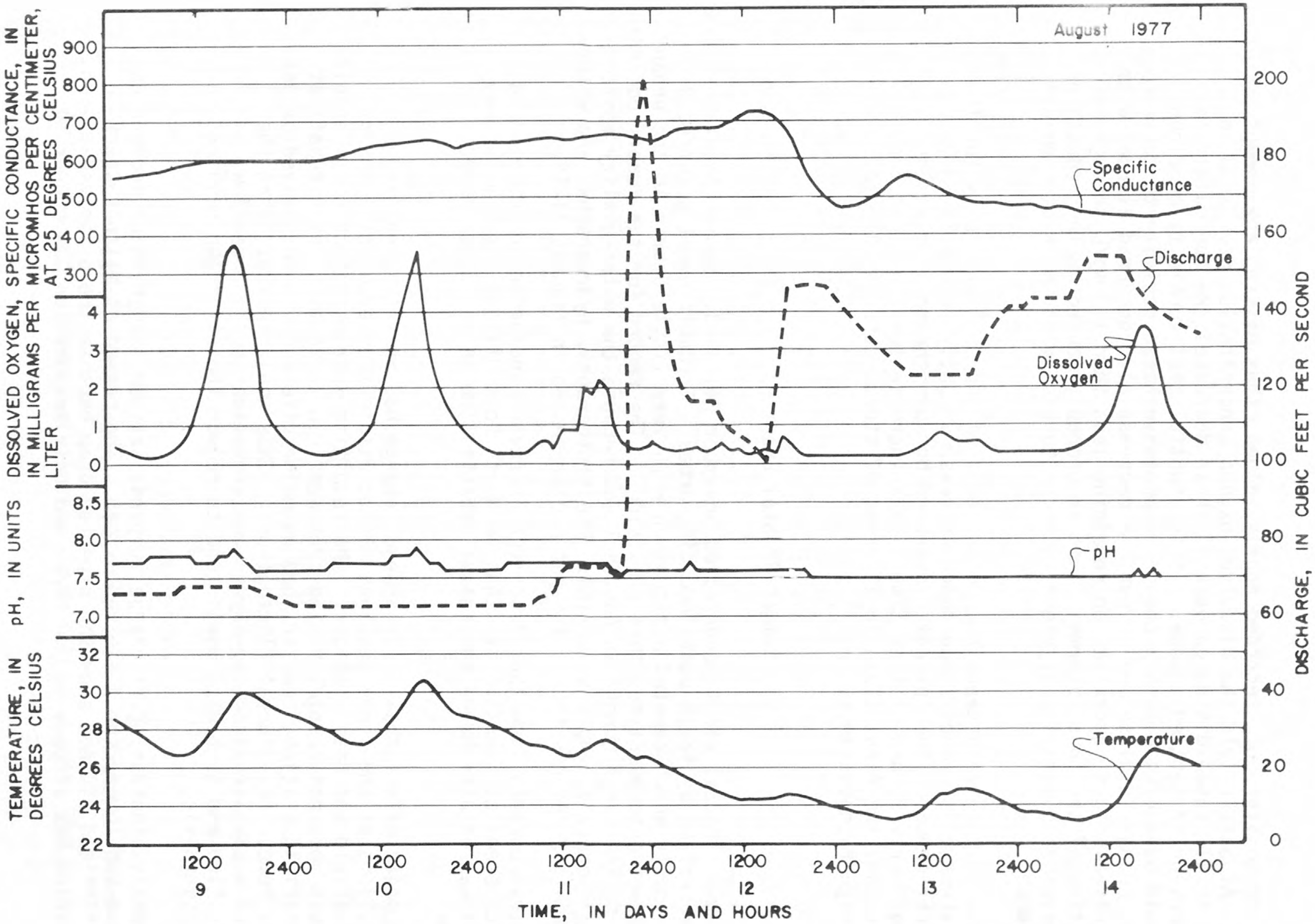

Figure 10. Water-quality monitor record for the summer convective event at James River near Boaz (fig. 1, sta. 6).

because the monitor only recorded hourly values, thus missing any abrupt changes. At Battlefield the dissolved-oxygen concentration decreased to 0.0 mg/L at all three discharge peaks. These decreases are due mainly to the suspension of settled sludge. It is doubtful that turbidity or cloud cover could have caused such a change in photosynthetic activity to cause an abrupt change in dissolved oxygen. A decrease also occurred at Boaz with the dissolved-oxygen concentration remaining less than 1.0 mg/L throughout the duration of the three storms. This is probably caused by the reduction of photosynthetic activity by cloud cover or turbidity and high biochemical oxygen demand.

The specific conductance records at Battlefield show that only for the first discharge peak does conductance increase slightly before it fails. This is not shown on the Springfield record because the monitor was only recording hourly values at this time. This increase for the first peak indicates that the first flush in a series of storms carries material causing higher conductance.

Summer Frontal Event

A summer frontal storm occurred on November 24, 1973. Summer frontal storms are characterized by large sustained discharges. A runoff event occurred 3 days previously which created a situation with very little debris in the urban areas and wet antecedent-moisture conditions. The record for the runoff occurring previous to the large runoff is not included because the water-quality monitors failed to operate during that period. The hyetographs, hydrographs, and water-quality monitor records for this event are presented in figures 11-15.

The hydrographs show that discharge increases and decreases more rapidly at Wilsons Creek at Scenic Drive than at North Fork Wilsons Creek at Highway 13. This can be attributed to greater urbanization in the Wilsons Creek watershed.

The major effect that this large discharge had on dissolved-oxygen concentrations at the three stations was to dilute the sewage effluent at the Battlefield and Boaz stations. The resulting increase at the Battlefield station was very noticeable, rising from near 0.0 to 10 mg/L. The runoff at the Springfield station, however, had no major effect on the dissolved oxygen except to remove the diurnal fluctuations. This would indicate that the runoff had a similar dissolved-oxygen concentration to the base flow. Turbulent flow and turbidity would tend to reduce the effect or respiration and photosynthesis.

Normally, increasing discharge suspends settled sludge which decomposes downstream and lowers the dissolved oxygen. The record at Wilsons Creek near Battlefield did not show the expected drop because the dissolved-oxygen concentration was already at 0.0 mg/L, and only respiration was occurring.

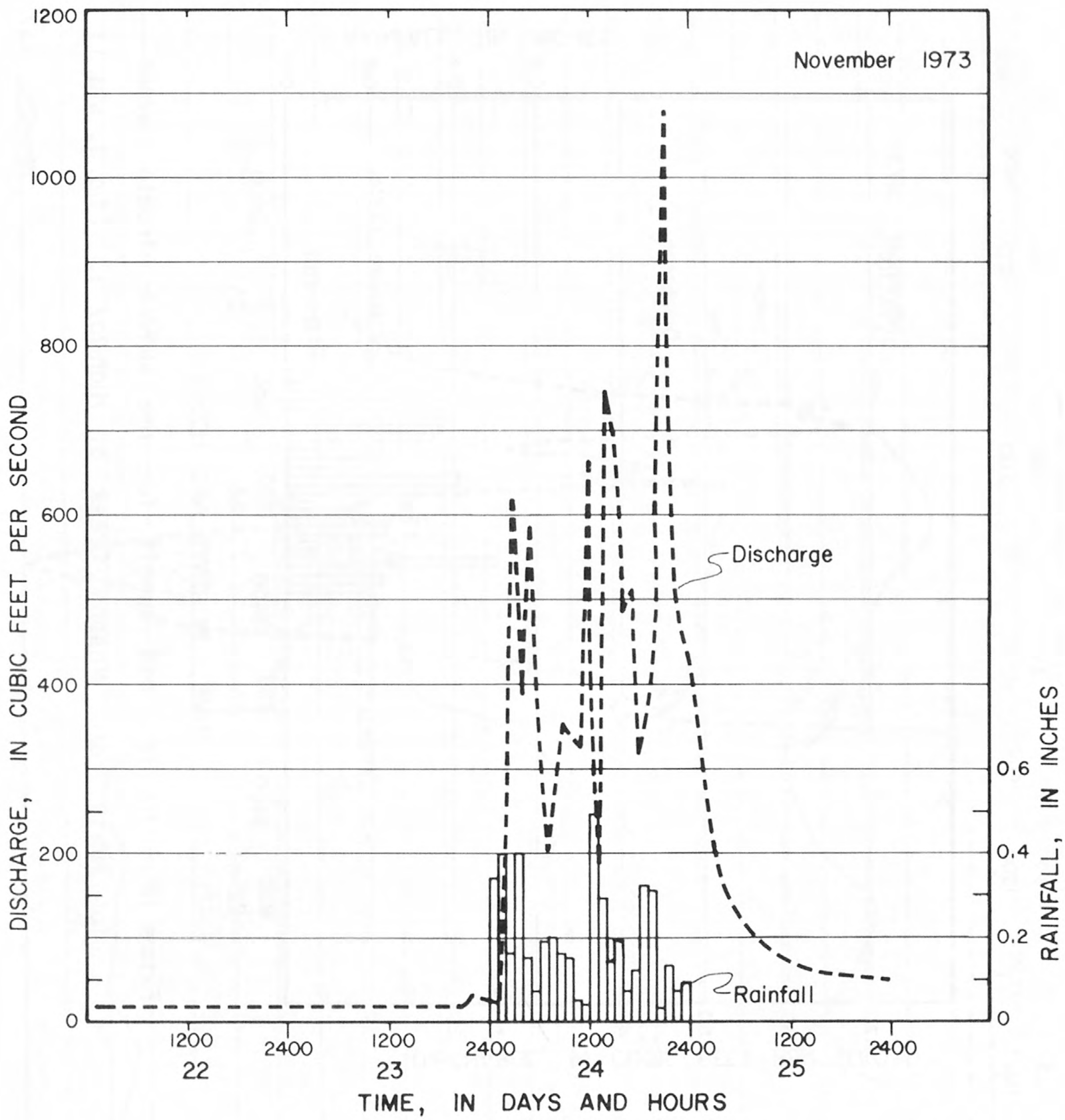

Figure 11. Rainfall and runoff for the summer frontal event for Wilsons Creek at Scenic Drive (fig. 1, sta. 2).

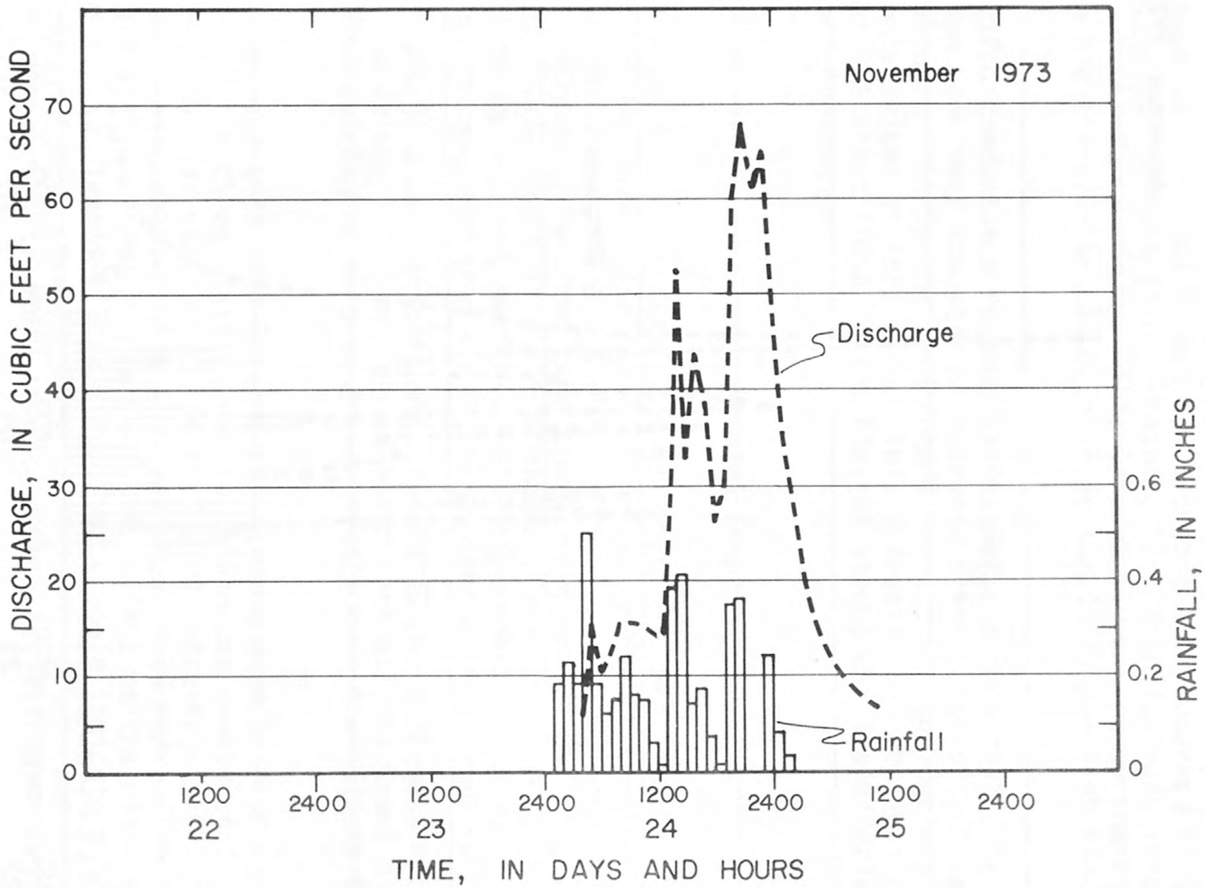

Figure 12. Rainfall and runoff for the summer frontal event for North Fork Wilsons Creek at Highway 13 (fig. 1, sta. 1).

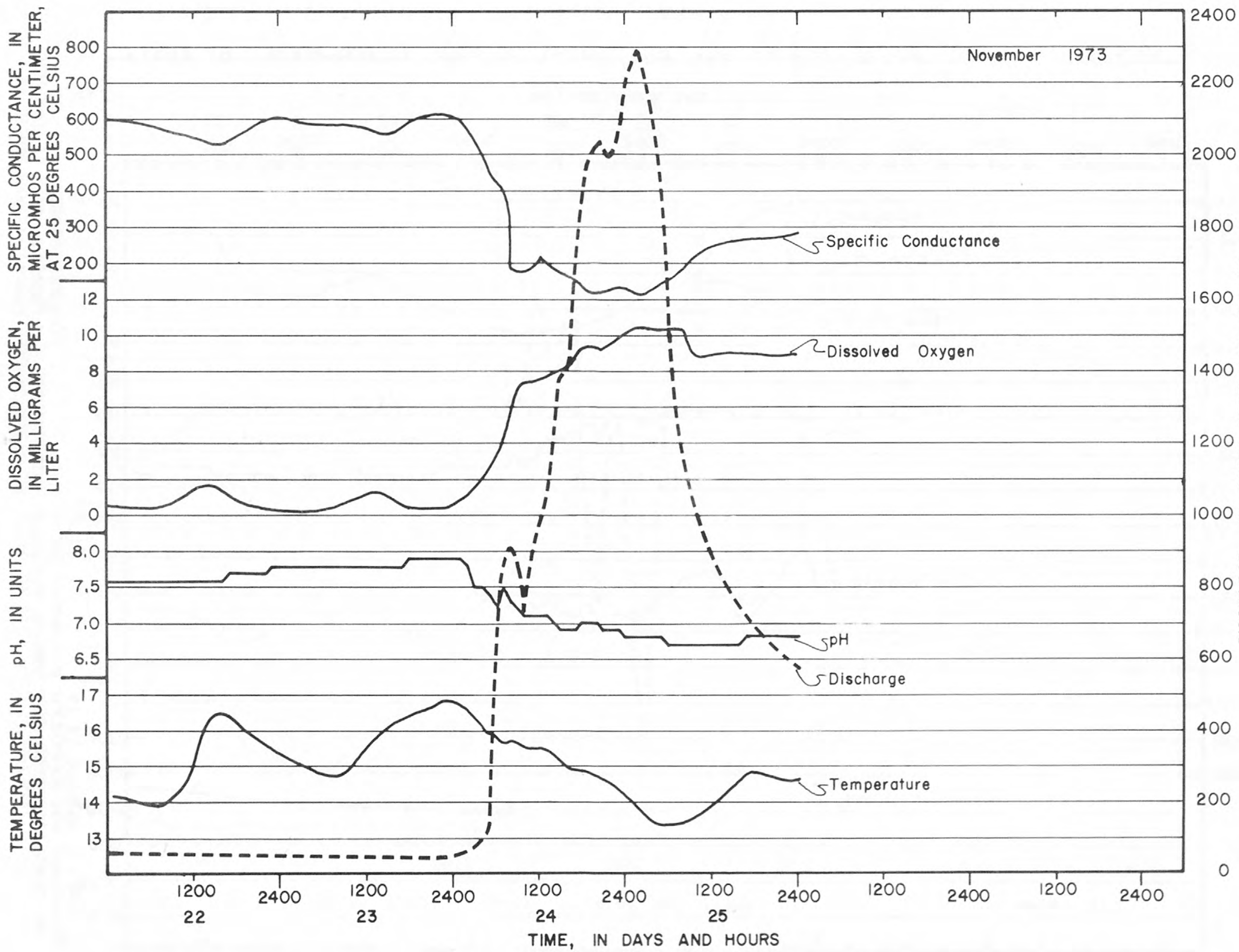

Figure 13. Water-quality monitor record for the summer frontal event at Wilsons Creek near Springfield (fig. 1, sta. 3).

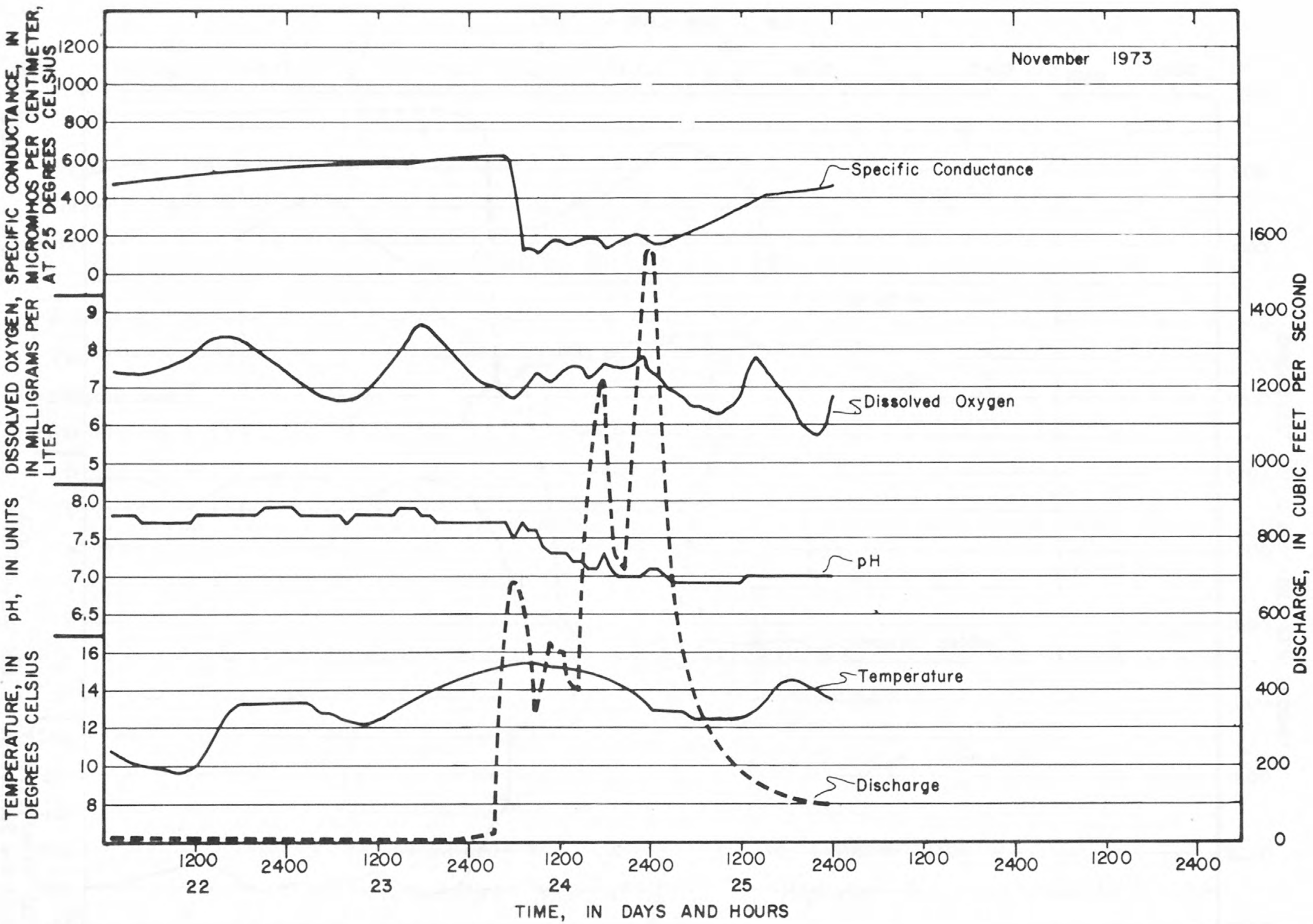

Figure 14. Water-quality monitor record for the summer frontal event at Wilsons Creek near Battlefield (fig. 1, sta. 4).

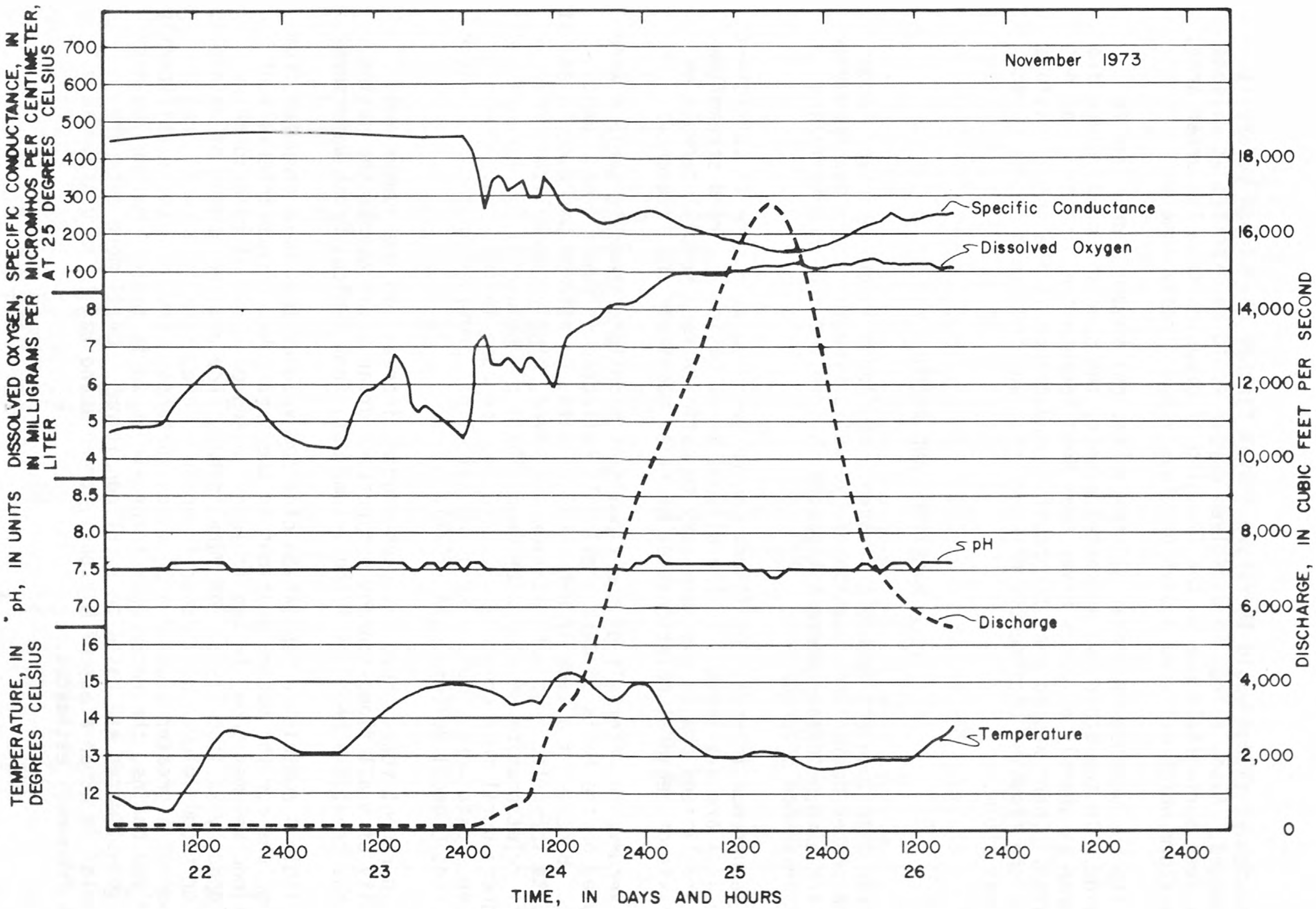

Figure 15. Water-quality monitor record for the summer frontal event at James River near Boaz (fig. 1, sta. 6).

The suspended sludge would therefore travel farther downstream before it decomposed. Also, a drop in dissolved oxygen would be expected at Wilsons Creek near Springfield due to the flushing of organics from the urban area, but a storm which occurred 3 days previously had already done this.

The conductance record at all three stations showed a drop due to dilution. In the other two presented events, the specific conductance did not drop as sharply at James River near Boaz because the discharge was not as large. There was no peak in specific conductance at the three stations due to the flushing of streets, parking lots, and industrial yards by the previous storm.

FLOOD MAGNITUDE AND FREQUENCY

The magnitude and probable frequency of floods is an important factor in the proper design and location of hydraulic structures. Flood-frequency data are also necessary where litigation is involved and in determining flood insurance coverage.

Recurrence intervals of floods can be computed at a site if sufficient flood data are available. In the Wilsons Creek basin, recorded streamflow data are limited and it was necessary to estimate recurrence intervals on the basis of regional relationships of flood magnitude and frequency.

Recurrence intervals of the flood-peak magnitude shown in table 4 were computed on the basis of data previously collected in rural areas (Hauth, 1974). Because of a lack of urban-runoff data, no attempt was made to adjust the data for effects of urbanization. However, highly generalized urban runoff relationships developed by Gann (1971) may be useful to planners and designers until more comprehensive studies are done in the area. The frequency data were computed by using guidelines provided in the U.S. Water Resources Council Bulletin 17A (1977).

In recent years there has been a great increase in the number and capacity of small flood-storage projects in urban areas across the nation. This has created a need for flood-volume data from typical urban watersheds.

Table 4 contains a tabulation of flood volumes that were computed from hydrographs for the gaging stations in the area. Recurrence intervals of the flood volumes shown in the table are based on regional relationships developed by Skelton (1973) for rural areas. For a given amount of rainfall, greater flood volumes will occur in an urban area than in a rural area because of a greater area of impervious surfaces. Thus for the significantly urbanized basins, the recurrence intervals shown in table 4 may be too high because estimates are based on rural conditions. Until more data are collected in urban areas of Missouri, there is no way to accurately adjust these frequency estimates.

Table 4.--Peak-flow and flood-volume data for gaging stations

				Annual Peaks			Flood-volume data						
								Flood-volume in ft^3/s, for indicated duration, in days			Estimated recurrence interval, in years, of largest flood volume for indicated duration, in days 1/		
Map number (fig. 1)	Station Name	Period of record	Drainage area (mi^2)	Water year	Peak (ft^3/s)	Estimated recurrence interval of highest peak, in years 1/	Water year	1	3	7	1	3	7
2	Wilsons Creek at Scenic Drive-------------	Oct. 1973-	17.8	1974	1,790	--	--	426	213	108	--	--	--
				1975	2,640	2	--	375	165	87	--	--	--
				1976	1,470	--	--	205	135	69	--	--	--
				1977	1,840	--	--	547	224	128	2	2	2
1	North Fork Wilsons Creek at State Highway 13------	Oct. 1973-	5.12	1974	1,000	--	--	119	60	30	--	--	--
				1975	206	--	--	77	46	24	--	--	--
				1976	1,200	--	--	57	38	19	--	--	--
				1977	1,400	2	--	181	72	40	<2	2	2
3	Wilsons Creek near Springfield-------------	Oct. 1972-	31.4	1973	2,840	--	1973	1,490	630	305	2	5	5
				1974	2,510	--	1974	848	513	268	--	--	--
				1975	2,720	--	1975	662	294	150	--	--	--
				1976	2,680	--	1976	358	233	119	--	--	--
				1977	3,320	4	1977	952	384	220	--	--	--
4	Wilsons Creek near Battlefield-------------	Mar. 1968- Sept. 1970, Oct. 1972-	55.0	1969	2,390	--	1969	988	687	418	--	--	--
				1970	2,420	--	1970	1,470	852	460	--	--	--
				1971	--	--	1971	--	--	--	--	--	--
				1972	--	--	1972	--	--	--	--	--	--
				1973	3,860	--	1973	2,350	1,330	734	8	10	10
				1974	2,820	--	1974	1,560	1,040	651	--	--	--
				1975	2,490	--	1975	1,350	773	488	--	--	--
				1976	2,130	--	1976	1,160	692	426	--	--	--
				1977	4,830	5	1977	1,550	740	443	--	--	--
5	James River near Boaz--------------------	Oct. 1972-	462	1973	31,400	10	1973	15,400	9,130	4,940	10	8	8
				1974	16,900	--	1974	14,000	8,040	4,980	--	--	8
				1975	11,500	--	1975	9,040	5,870	3,430	--	--	--
				1976	9,800	--	1976	6,890	5,600	3,450	--	--	--
				1977	23,000	--	1977	10,600	7,133	3,790	--	--	--

1/ Based on relationships for rural areas

SUMMARY AND CONCLUSIONS

In order to study the problems associated with urban storm runoff and wastewater effluent in Wilsons Creek basin, a network of streamgaging and water-quality stations was established. Data from this network of stations have been used to document hydrologic conditions in the basin prior to the upgrading of the Southwest Wastewater Plant. The data have also been used to make flood-frequency estimates, although it was not possible to fully account for urban effects because of scant data.

Statistical T tests conducted on the means of water-quality parameters collected monthly at two stations on the James River, located upstream and downstream from the confluence of Wilsons Creek, showed that there was a significant difference in all parameters except temperature and dissolved silica at the 0.05 probability level. High regression correlation occurred for discharge with dissolved sodium, dissolved potassium, and dissolved chloride, and for specific conductance with dissolved sodium, dissolved chloride and dissolved sulfate at the Boaz station, while the Wilsons Creek station had lower correlation for these relationships. This is due to the influence of a consistent quality of effluent from the Southwest Wastewater Plant on the Boaz station.

The effluent from the Southwest Wastewater Plant has a major effect on the dissolved oxygen in lower Wilsons Creek and James River. The effect is much greater during the summer than in the winter.

Rainfall flushes poor-quality water into Wilsons Creek from streets, parking lots, and industrial yards. This poor-quality water is of short duration, momentarily raising the conductance and lowering the dissolved oxygen. As shown at the Wilsons Creek near Springfield station, the lowering of dissolved oxygen from the runoff is not as great as the lowering from discharging treatment-plant effluent. This is because the runoff effect is of a much shorter duration while the effect of sewage effluent is constant. Overall, runoff events have the effect of diluting the sewage effluent in the water, thus upgrading the water quality in the stream.

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